METALLOGRAPHIC STANDARDS

OF THE BUREAU OF STEAM ENGINEERING

FOR

STEEL FORGINGS

ISSUED BY THE NAVY DEPARTMENT
JANUARY 2, 1917

¶ To be used in connection with the latest edition of the specifications for steel forgings issued by the Navy Department (49-S-2)

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GOVERNMENT PRINTING OFFICE
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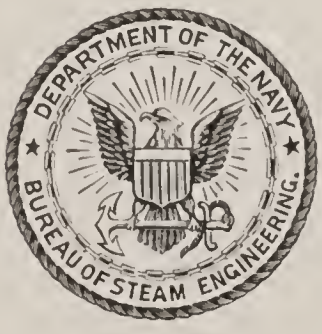

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METALLOGRAPHIC STANDARDS

OF THE

BUREAU OF STEAM ENGINEERING

FOR

STEEL FORGINGS.

The illustrations contained in this pamphlet compose the metallographic standards of the Bureau of Steam Engineering for various classes of steel. They illustrate structures which are acceptable and unacceptable to the Bureau of Steam Engineering according to whether they do or do not conform to the metallographic requirements included in the specifications for steel forgings.

All the specimens from which the photographs were taken were etched with picric acid, and the illustration is reproduced from the photograph and represents the structure at a magnification of 100. The photographs were all taken by arc light, the eyepiece used was a 10-power, the objective 16 mm., and the exposure 2 seconds.

REFERENCE:
S. E. 206326-710-S, Nov. 25, 1916.

S. & A., 380-789.

Test No. 582. Card No. 8. Inclosure (H).

CHEMICAL ANALYSIS.

C	S	Mn	Si	P	Cr	V
.37	.023	.56	.158	.010	.99	.17

PHYSICAL TESTS.

Tensile strength.	Yield point.	Elongation (per cent in 2 inches).	Per cent reduction.	Bend.
109500	107000	22	65.2	O. K.

The above illustration represents a structure which is desired by the Bureau of Steam Engineering for class alloy steel forgings.

Heat treatment.—The structure represented was obtained by oil quenching followed by annealing.

The white areas represent ferrite. The black areas represent sorbitic pearlite.

This specimen was taken from a crank-shaft forging. The grain size is unusually fine.

Test No. 582. Card No. 5. Inclosure (E).

CHEMICAL ANALYSIS.

C	S	Mn	Si	P	Cr	V
.37	.023	.56	.158	.010	.99	.17

PHYSICAL TESTS.

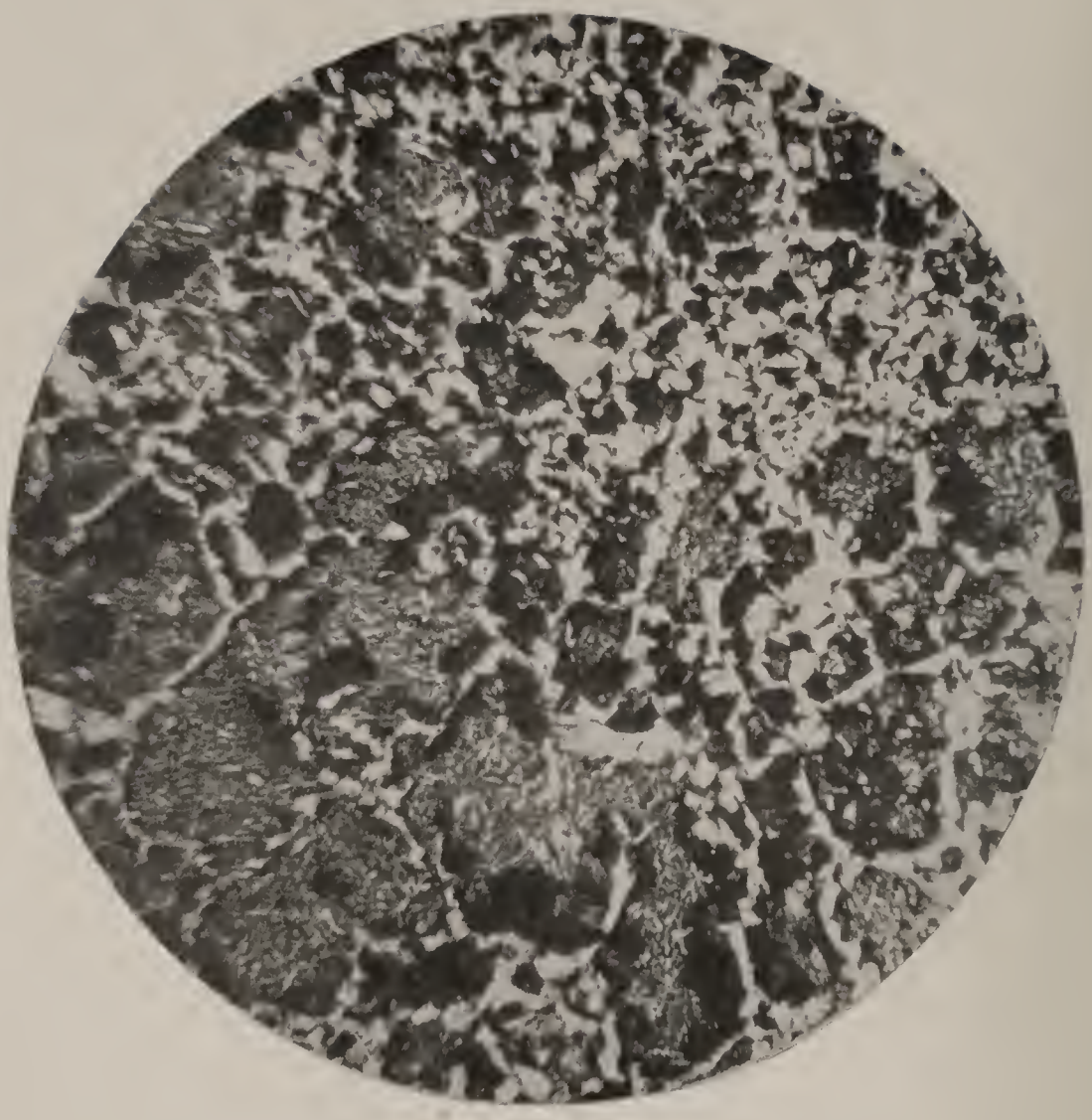
Tensile strength.	Yield point.	Elongation (per cent in 2 inches).	Per cent reduction.	Bend.
111840	108580	22.8	64.04	O. K.

The above illustration represents a structure which is **acceptable** to the Bureau of Steam Engineering for class alloy steel forgings.

Heat treatment.—The structure represented was obtained by oil quenching followed by annealing.

The white areas represent ferrite. The black areas represent sorbitic pearlite.

This specimen was taken from a crank-shaft forging. Though the grain size is moderate, a finer structure could be obtained with this class of material.



Test No. 393. Card No. 6. Inclosure (F).

CHEMICAL ANALYSIS.

C	S	Mn	Si	P	Cr	V
.28	.027	.53	.160	.008	.78	.18

PHYSICAL TESTS.

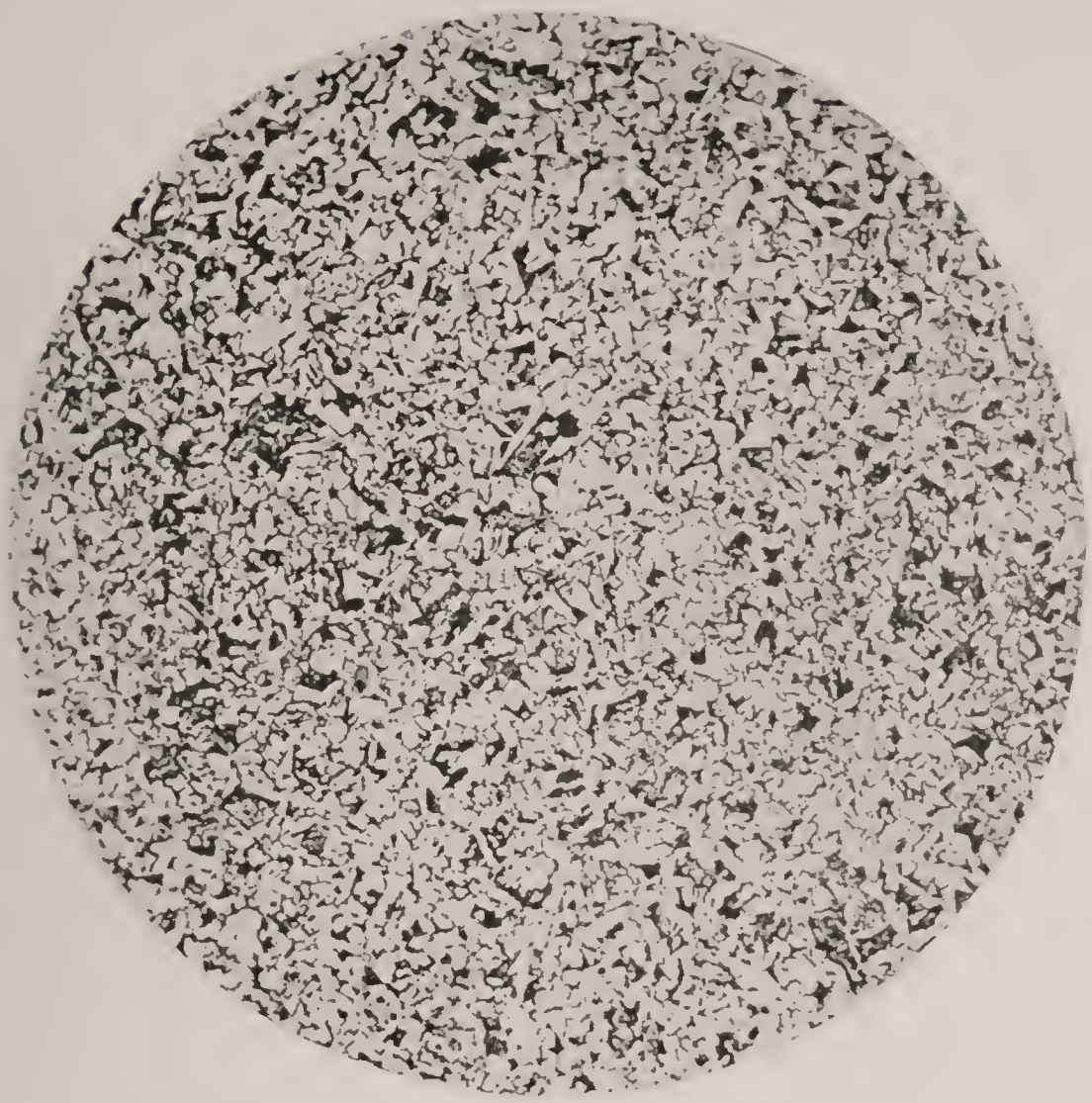
Tensile strength.	Yield point.	Elongation (per cent in 2 inches).	Per cent reduction.	Bend.
117000	107500	22	61	O. K.

The above illustration represents a structure which is **not acceptable** to the Bureau of Steam Engineering for class alloy steel forgings.

Heat treatment.—The structure represented was obtained by oil quenching followed by annealing.

The white areas represent ferrite. The halftone areas represent pearlite and sorbite.

This specimen was taken from a crank-shaft forging for a submarine. This structure is nonuniform. In some places the grain size is small and there is much free ferrite. In other regions a large grain size is found.



Test No. 558B. Card No. 1. Inclosure (A–1).

CHEMICAL ANALYSIS.

C	S	Mn	Si	P	Ni
.270	.042	.45	.110	.027	3.33

PHYSICAL TESTS.

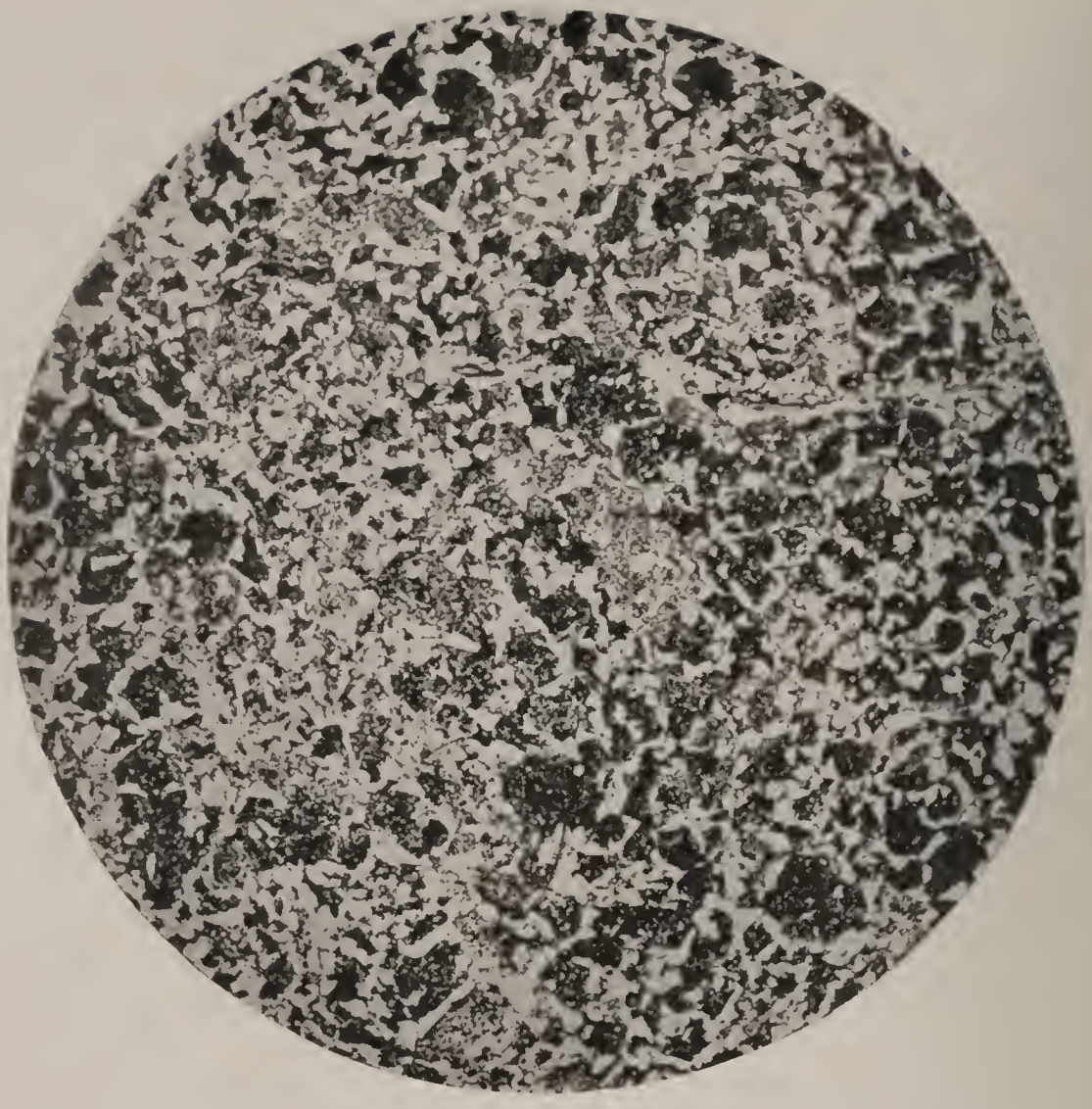
Tensile strength.	Yield point.	Elongation (per cent in 2 inches).	Per cent reduction.	Bend.
85250		29.5	62.43	O. K.

The above illustration represents a structure which is desired by the Bureau of Steam Engineering for Class An steel forgings.

Heat treatment.—The structure represented was obtained by annealing.

The white areas represent ferrite. The black areas represent pearlite.

This specimen was taken from a collar for shafting for a battleship. This structure is very fine grained and uniform.



Test No. 695. Card No. 00. Inclosure (—).

CHEMICAL ANALYSIS.

C	S	Mn	Si	P	Ni
.40	.016	.62	.142	.006	3.32

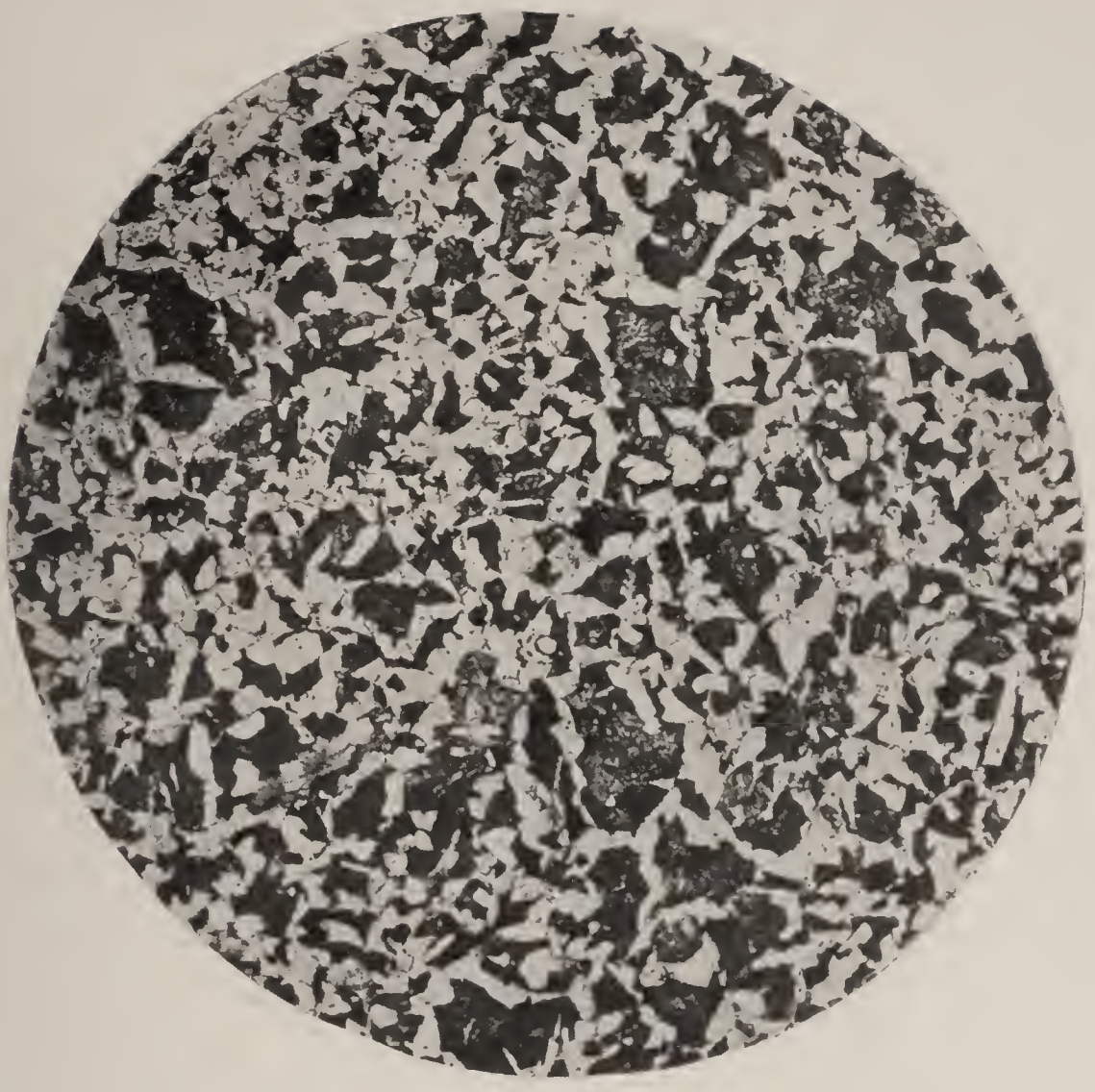
PHYSICAL TESTS.

Tensile strength.	Yield point.	Elongation (per cent in 2 inches).	Per cent reduction.	Bend.
90000	51500	29.0	52.5	O. K.

The above illustration represents a structure which is **acceptable** to the Bureau of Steam Engineering for Class An steel forgings.

Heat treatment.—The structure represented was obtained by annealing. The white areas represent ferrite. The black areas represent pearlite.

This specimen was taken from a line-shaft forging for a battleship. The grain size is satisfactory and the structure is free from segregation of ferrite and pearlite.



Test No. 556A. Card No. 13. Inclosure (E–5).

CHEMICAL ANALYSIS.

C	S	Mn	Si	P	Ni
.268	.038	.67	.163	.023	3.49

PHYSICAL TESTS.

Tensile strength.	Yield point.	Elongation (per cent in 2 inches).	Per cent reduction.	Bend.
89600	56900	28.1	55.3	O. K.

The above illustration represents a structure which is **acceptable** to the Bureau of Steam Engineering for Class An steel forgings.

Heat treatment.—The structure represented was obtained by double annealing.

The white areas represent ferrite. The black areas represent pearlite.

This specimen was taken from a line-shaft forging for a torpedo-boat destroyer. The grain size is moderate. A finer structure, however, could be obtained with this class of material.

Test No. 558B. Card No. 8. Inclosure (C–4).

CHEMICAL ANALYSIS.

C	S	Mn	Si	P	Ni
.290	.042	.67	.165	.024	3.62

PHYSICAL TESTS.

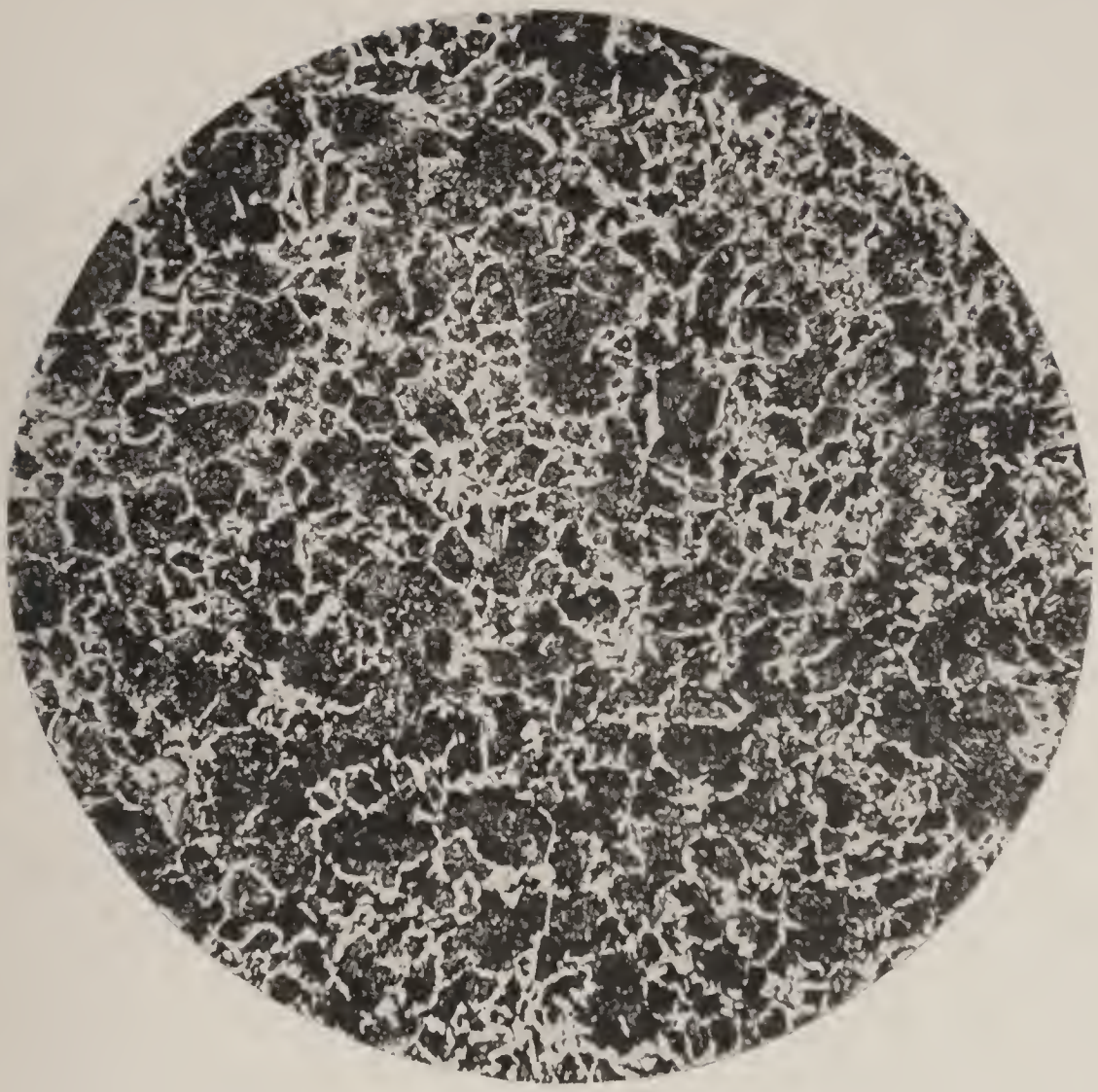
Tensile strength.	Yield point.	Elongation (per cent in 2 inches).	Per cent reduction.	Bend.
87500	54300	27.4	54.05	O. K.

The above illustration represents a structure which is **not acceptable** to the Bureau of Steam Engineering for Class An steel forgings.

Heat treatment.—The structure represented was obtained by annealing.

The white areas represent ferrite. The black areas represent pearlite.

This specimen was taken from a sleeve coupling for shafting for a battleship. The structure is considerably coarser than it should be. The grain size exceeds that allowed in the specifications.



Test No. 511. Card No. 4. Inclosure (D).

CHEMICAL ANALYSIS.

C	S	Mn	P
.50	.024	.53	.015

PHYSICAL TESTS.

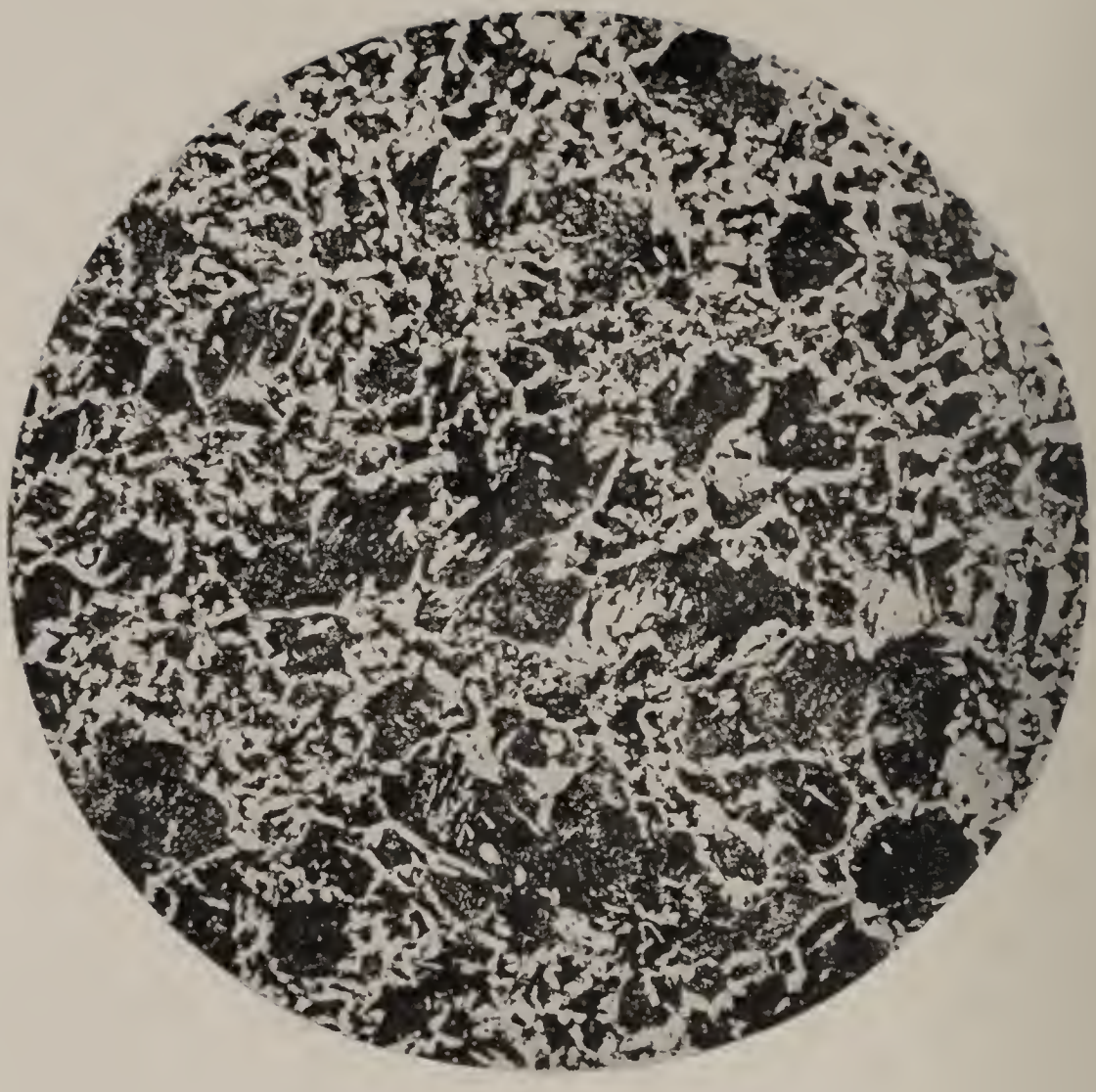
Tensile strength.	Yield point.	Elongation (per cent in 2 inches).	Per cent reduction.	Bend.
86500	62500	31.5		O. K.

The above illustration represents a structure which is **acceptable** to the Bureau of Steam Engineering for Class Ac steel forgings.

Heat treatment.—The structure represented was obtained by oil quenching followed by annealing.

The white areas represent ferrite. The black areas represent sorbitic pearlite.

This specimen was taken from a propeller-shaft forging for a battleship. The grain size is moderate and the distribution of ferrite and pearlite is fairly uniform.



Test No. 511. Card No. 3. Inclosure (C).

CHEMICAL ANALYSIS.

C	S	Mn	P
.50	.024	.53	.015

PHYSICAL TESTS.

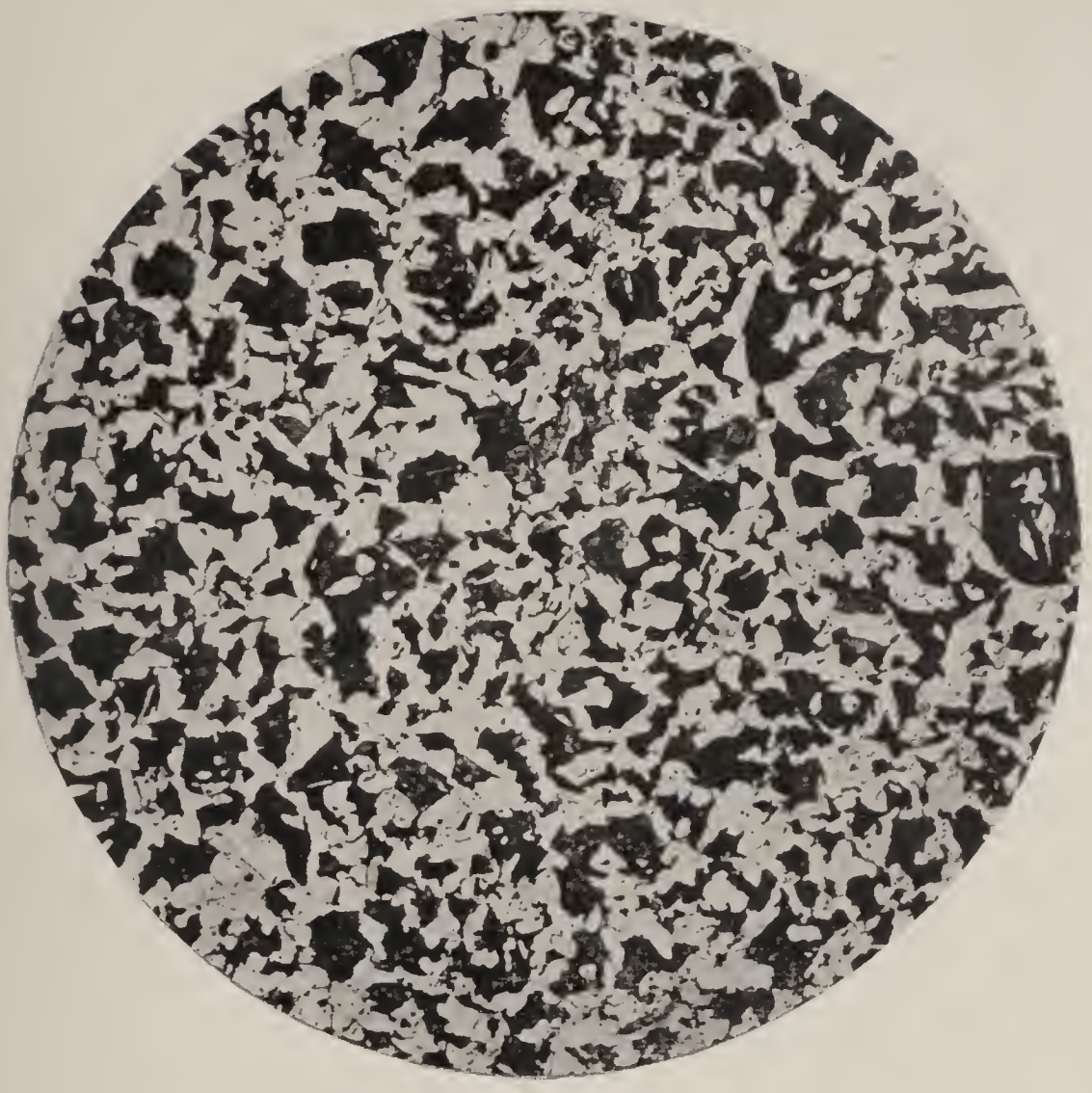
Tensile strength.	Yield point.	Elongation (per cent in 2 inches).	Per cent reduction.	Bend.
80120	52750	31.5		O. K.

The above illustration represents a structure which is **acceptable** to the Bureau of Steam Engineering for Class Ac steel forgings.

Heat treatment.—The structure represented was obtained by oil quenching followed by annealing.

The white areas represent ferrite. The black areas represent sorbitic pearlite.

This specimen was taken from a propeller-shaft forging for a battleship. Though the grains in some places measure about one-half inch in diameter, the structure can be considered acceptable. A finer structure is desirable.



Test No. 675. Card No. 33. Inclosure (N–1).

CHEMICAL ANALYSIS.

C	S	Mn	Si	P
.43	.027	.53	.137	.004

PHYSICAL TESTS.

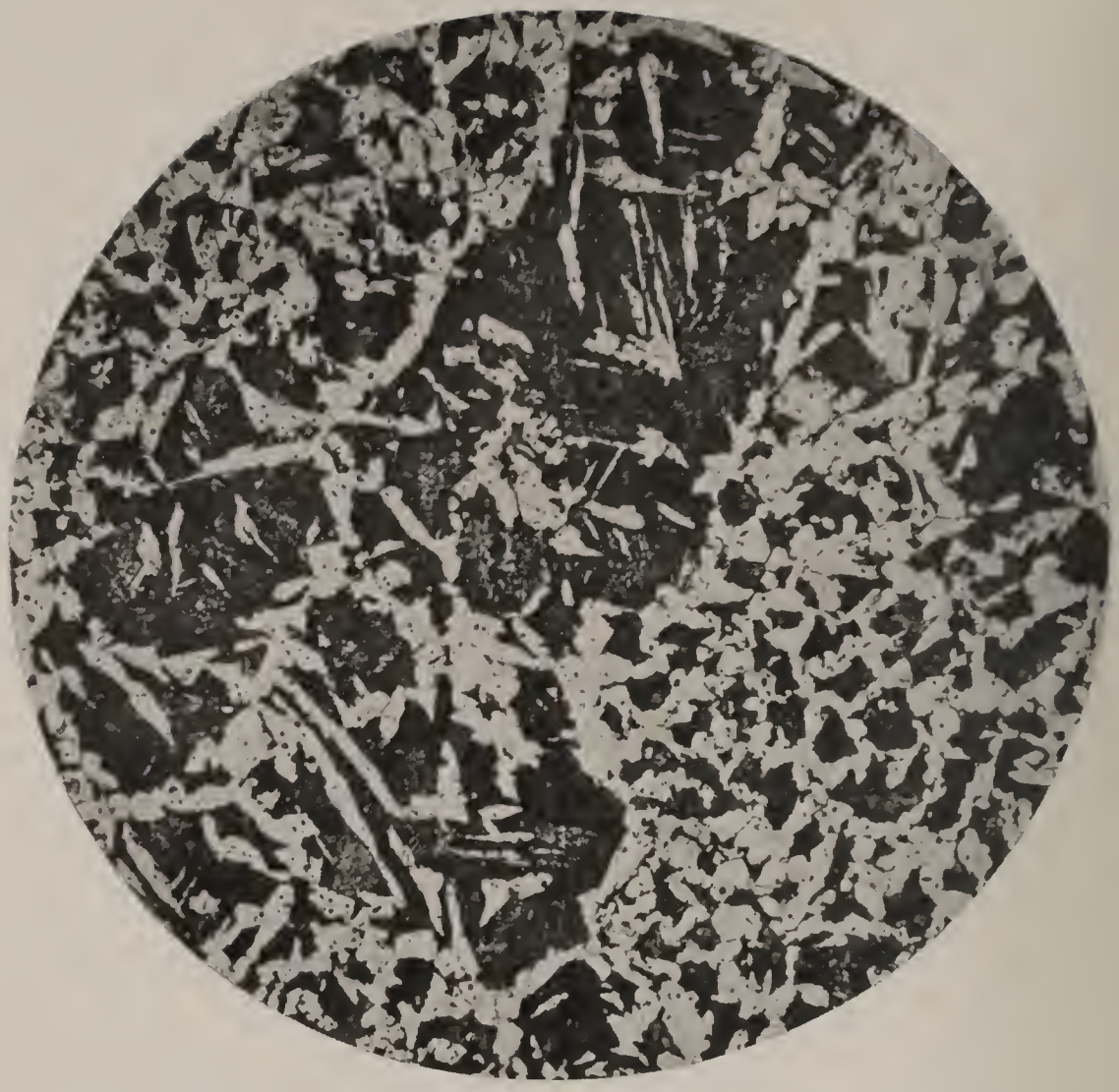
Tensile strength.	Yield point.	Elongation (per cent in 2 inches).	Per cent reduction.	Bend.
78900	42000	28.2	47.4	O. K.

The above illustration represents a structure which is **acceptable** to the Bureau of Steam Engineering for class B special steel forgings.

Heat treatment.—The structure represented was obtained by annealing.

The white areas represent ferrite. The black areas represent pearlite.

This specimen was taken from a crank-shaft forging for a submarine. The grain size is moderate and the structure is uniform.



Test No. 675. Card No. 36. Inclosure (N–4).

CHEMICAL ANALYSIS.

C	S	Mn	Si	P
.43	.027	.53	.137	.004

PHYSICAL TESTS.

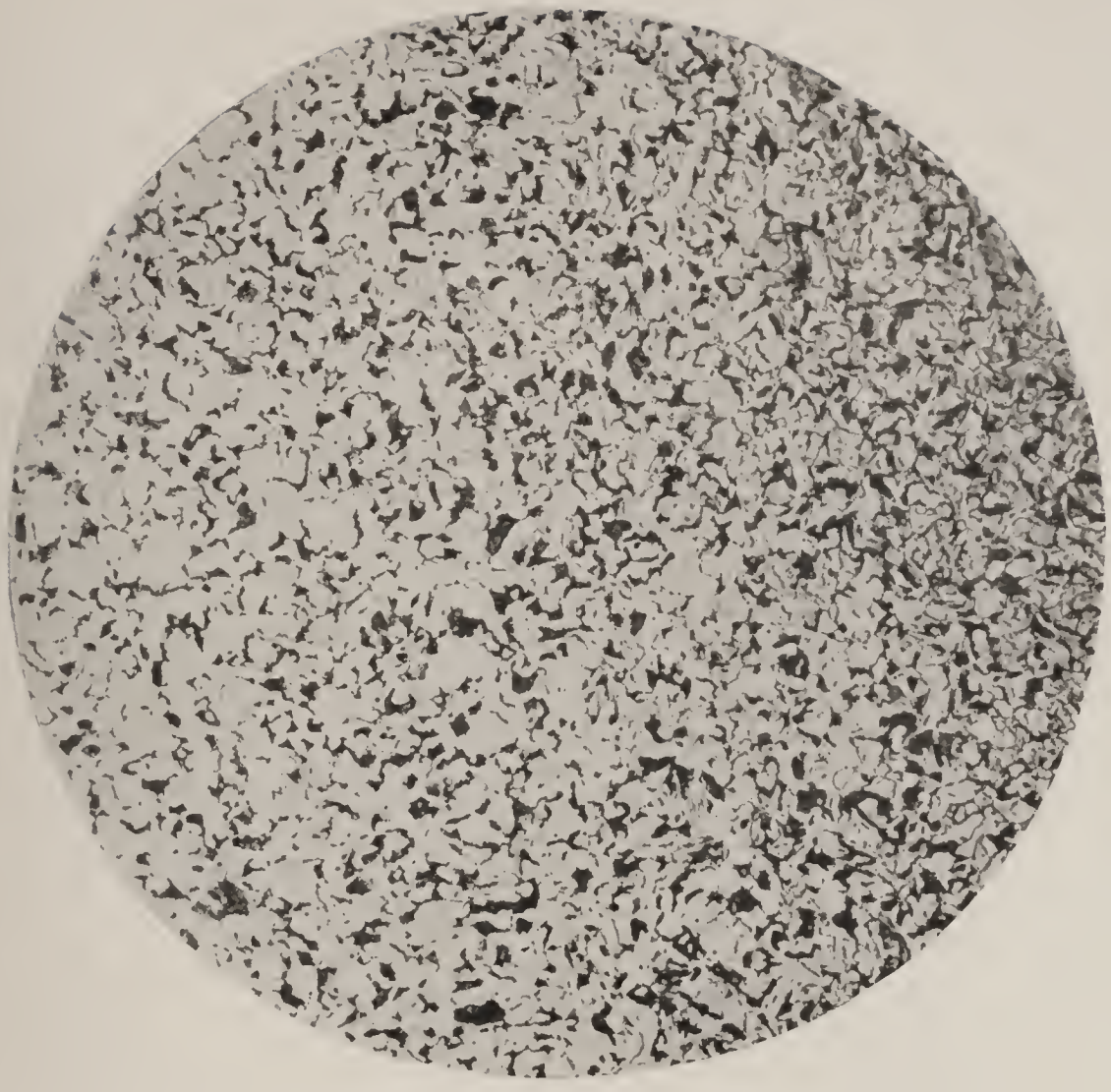
Tensile strength.	Yield point.	Elongation (per cent in 2 inches).	Per cent reduction.	Bend.
78900	42000	28.2	47.4	O. K.

The above illustration represents a structure which is **not acceptable** to the Bureau of Steam Engineering for Class B special steel forgings.

Heat treatment.—The structure represented was obtained by annealing.

The white areas represent ferrite. The black areas represent pearlite.

This specimen was taken from a crank-shaft forging for a submarine. This structure is nonuniform. Regions of coarse network are surrounded by regions of fine structure.



Test No. 638D. Card No. 33. Inclosure (Q–2).

CHEMICAL ANALYSIS.

C	S	Mn	Si	P
.32	.021	.50	.145	.018

PHYSICAL TESTS.

Tensile strength.	Yield point.	Elongation (per cent in 2 inches).	Per cent reduction.	Bend.
71025	41425	35.0	59.9	O. K.

The above illustration represents a structure which is **desired** by the Bureau of Steam Engineering for Class B steel forgings.

Heat treatment.—The structure represented was obtained by simple annealing.

The white areas represent ferrite. The black areas represent pearlite.

This specimen was taken from a propeller-shaft forging for a submarine. The fine-grained structure, obtained by simple annealing, is evidence of what can be accomplished in the heat treatment of Class B steel.

Test No. 583. Card No. 00. Inclosure ( ).

CHEMICAL ANALYSIS.

C	S	Mn	P
.38	.036	.49	.014

PHYSICAL TESTS.

Tensile strength.	Yield point.	Elongation (per cent in 2 inches).	Per cent reduction.	Bend.
62750	31750	30.5	40.3	O. K.

The above illustration represents a structure which is **acceptable** to the Bureau of Steam Engineering for Class B steel forgings.

Heat treatment.—The structure represented was obtained by annealing.

The white areas represent ferrite. The black areas represent pearlite.

This specimen was taken from a thrust-shaft forging for a supply ship. Size of forging, 26 inches by 20 feet. Though the grain size is larger than it should be, the structure is acceptable for this class of steel.

Test No. 583A. Card No. 8. Inclosure (H).

CHEMICAL ANALYSIS.

C	S	Mn	P
.35	.045	.40	.04

PHYSICAL TESTS.

Tensile strength.	Yield point.	Elongation (per cent in 2 inches).	Per cent reduction.	Bend.
61750	32800	33.5	49.4	O. K.

The above illustration represents a structure which is **acceptable** to the Bureau of Steam Engineering for class B steel forgings.

Heat treatment.—The structure represented was obtained by annealing. The white areas represent ferrite. The black areas represent pearlite. This specimen was taken from an eccentric-rod forging. The structure, though not as fine as it should be, is acceptable.

Test No. 444F. Card No. 4. Inclosure (D).

CHEMICAL ANALYSIS.

C	S	Mn	P
.40	.033	.51	.022

PHYSICAL TESTS.

Tensile strength.	Yield point.	Elongation (per cent in 2 inches).	Per cent reduction.	Bend.
77520	38070	27.1		O. K.

The above illustration represents a structure which is **not acceptable** to the Bureau of Steam Engineering for Class B steel forgings.

Heat treatment.—The structure represented was obtained by oil quenching followed by annealing.

The white areas represent ferrite. The black areas represent pearlite.

This specimen was taken from a crank-shaft forging for a torpedo-boat destroyer. The large grain size renders this forging unsuitable for use in shafting. It has evidently been considerably overheated.

Test No. 527. Card No. 3. Inclosure (C).

CHEMICAL ANALYSIS.

C	S	Mn	P
.33	.023	.56	.012

PHYSICAL TESTS.

Tensile strength.	Yield point.	Elongation (per cent in 2 inches).	Per cent reduction.	Bend.
66000	34000	30.0		O. K.

The above illustration represents a structure which is **not acceptable** to the Bureau of Steam Engineering for Class B steel forgings.

Heat treatment.—The structure represented was obtained by annealing.

The white areas represent ferrite. The black areas represent pearlite.

This specimen was taken from a 9-inch round bar 20 feet long. Remnants of a very large grain occupy almost the entire field of view. Such a coarse triangular structure is known as ingotism.

Test No. 444C. Card No. 17. Inclosure (Q).

CHEMICAL ANALYSIS.

C	S	Mn	P
.33	.035	.53	.010

PHYSICAL TESTS.

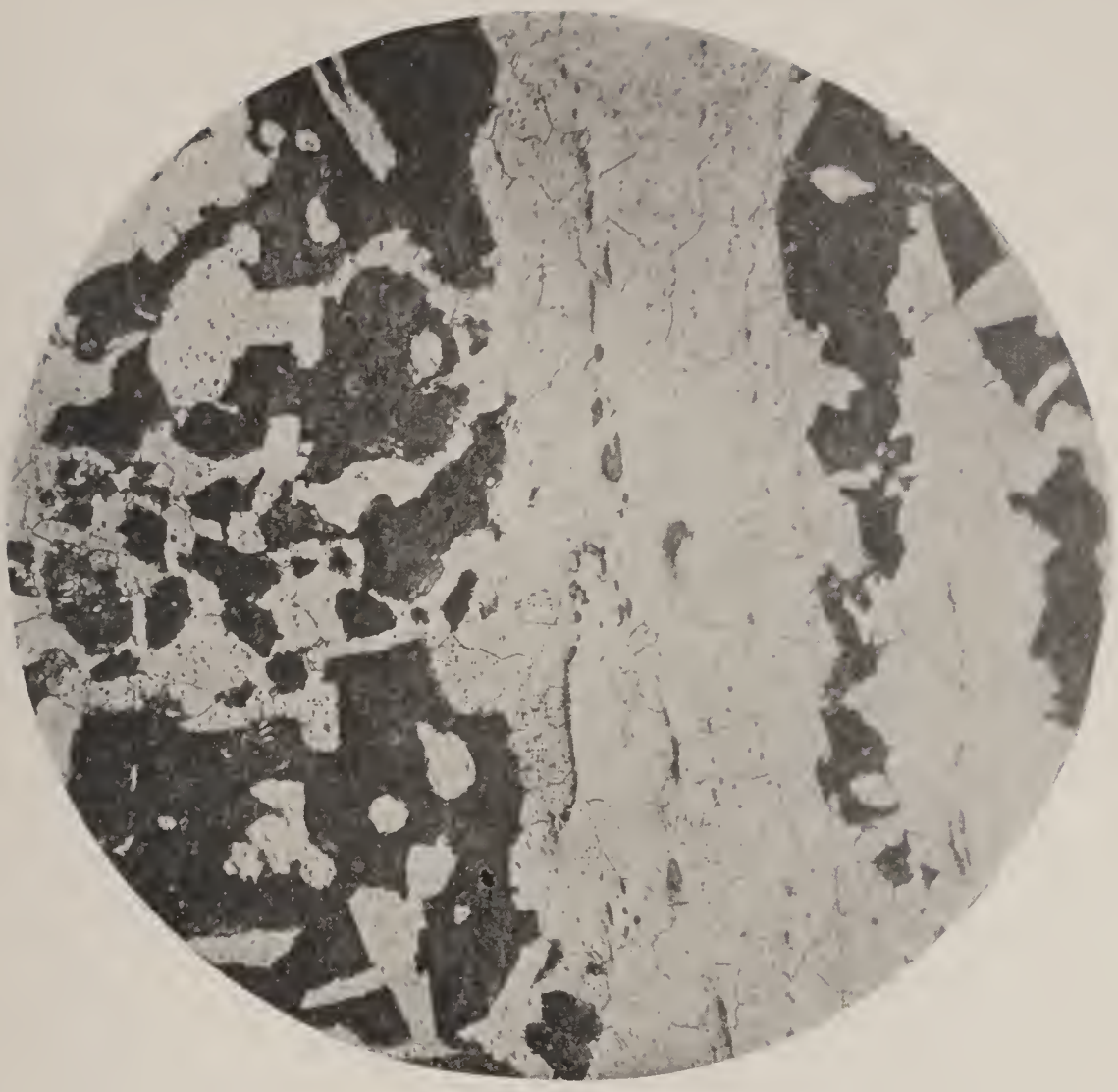
Tensile strength.	Yield point.	Elongation (per cent in 2 inches).	Per cent reduction.	Bend.
72890	39300	30.0		O. K.

The above illustration represents a structure which is **not acceptable** to the Bureau of Steam Engineering for Class B steel forgings.

Heat treatment.—The structure represented was obtained by oil quenching followed by annealing.

The white areas represent ferrite. The black areas represent sorbitic pearlite.

This specimen was taken from a crank-shaft forging for a submarine. Several groups of constituents, which originally formed large austenite grains, are here shown. Such a coarse structure is unsuitable for shafting.



Test No. 583A. Card No. 14. Inclosure (N).

CHEMICAL ANALYSIS.

C	S	Mn	P
.35	.045		.04

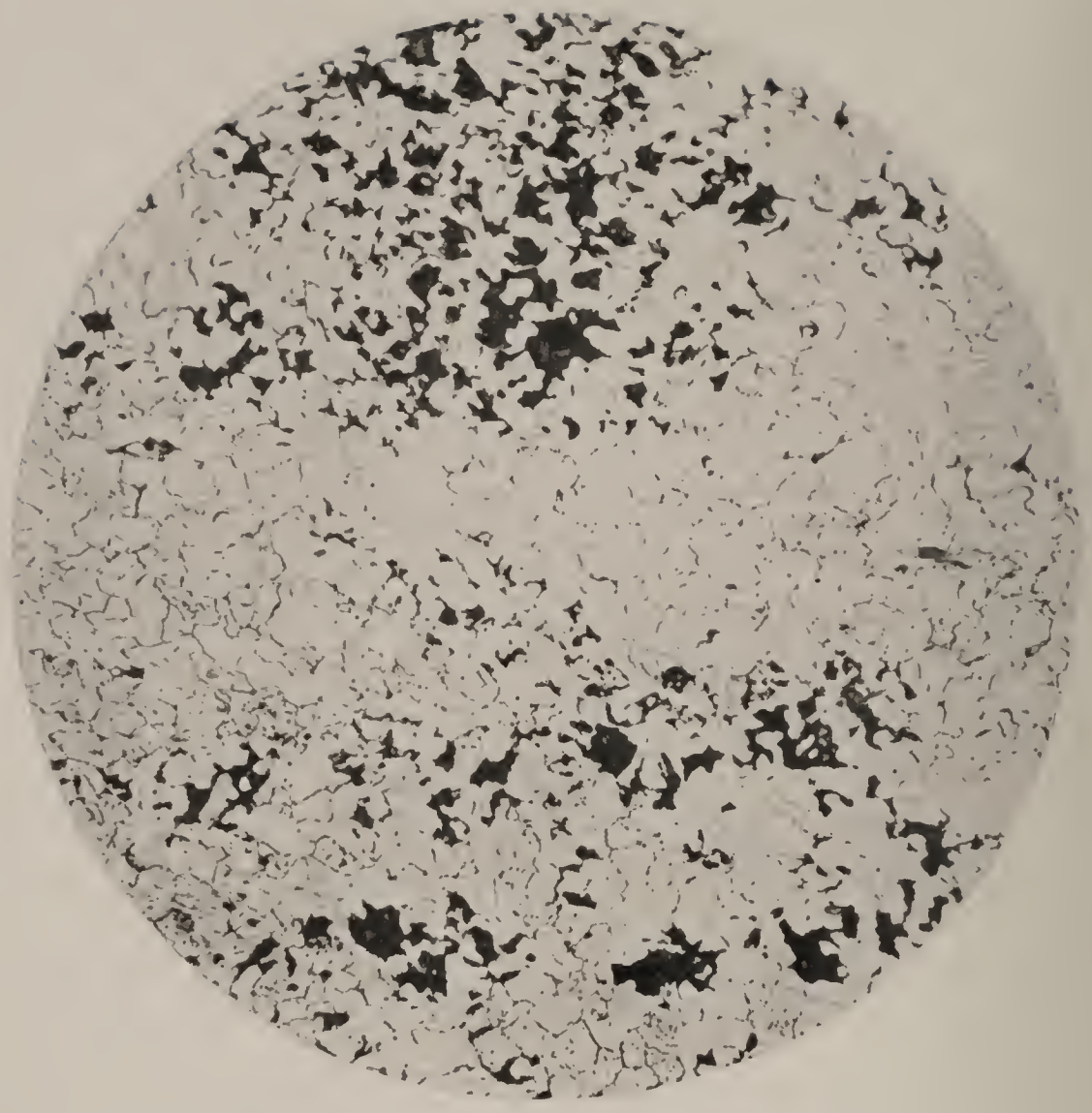
PHYSICAL TESTS.

Tensile strength.	Yield point.	Elongation (per cent in 2 inches).	Per cent reduction.	Bend.
61750	32800	33.5	49.4	O. K.

The abovei llustration represents a structure which is **not acceptable** to the Bureau of Steam Engineering for Class B steel forgings.

Heat treatment.—The structure represented was obtained by annealing. The white areas represent ferrite. The black areas represent pearlite.

This specimen was taken from a piston-rod forging for a transport. The broad ferrite streaks, containing segregated particles of manganese sulphide, render the forging unsuitable for use in shafting. The grain size is also larger than allowed.



Test No. 630F. Card No. 14. Inclosure (G–2).

CHEMICAL ANALYSIS.

C	S	Mn	Si	P
.245	.031	.513	.213	.027

PHYSICAL TESTS.

Tensile strength.	Yield point.	Elongation (per cent in 2 inches).	Per cent reduction.	Bend.
68250	39500	31.5	52.3	O. K.

The above illustration represents a structure which is **not acceptable** to the Bureau of Steam Engineering for Class B steel forgings.

Heat treatment.—The structure represented was obtained by annealing.

The white areas represent ferrite. The black areas represent pearlite.

This specimen was taken from a propeller-shaft forging for a submarine. This structure is far from homogeneous. Irregular streaks and patches of ferrite and pearlite, i. e., decided segregation of the normal constituents, are here shown.

Test No. 558B. Card No. 5. Inclosure (C–1).

CHEMICAL ANALYSIS.

C	S	Mn	Si	P	Ni
.290	.042	.67	.165	.024	3.62

PHYSICAL TESTS.

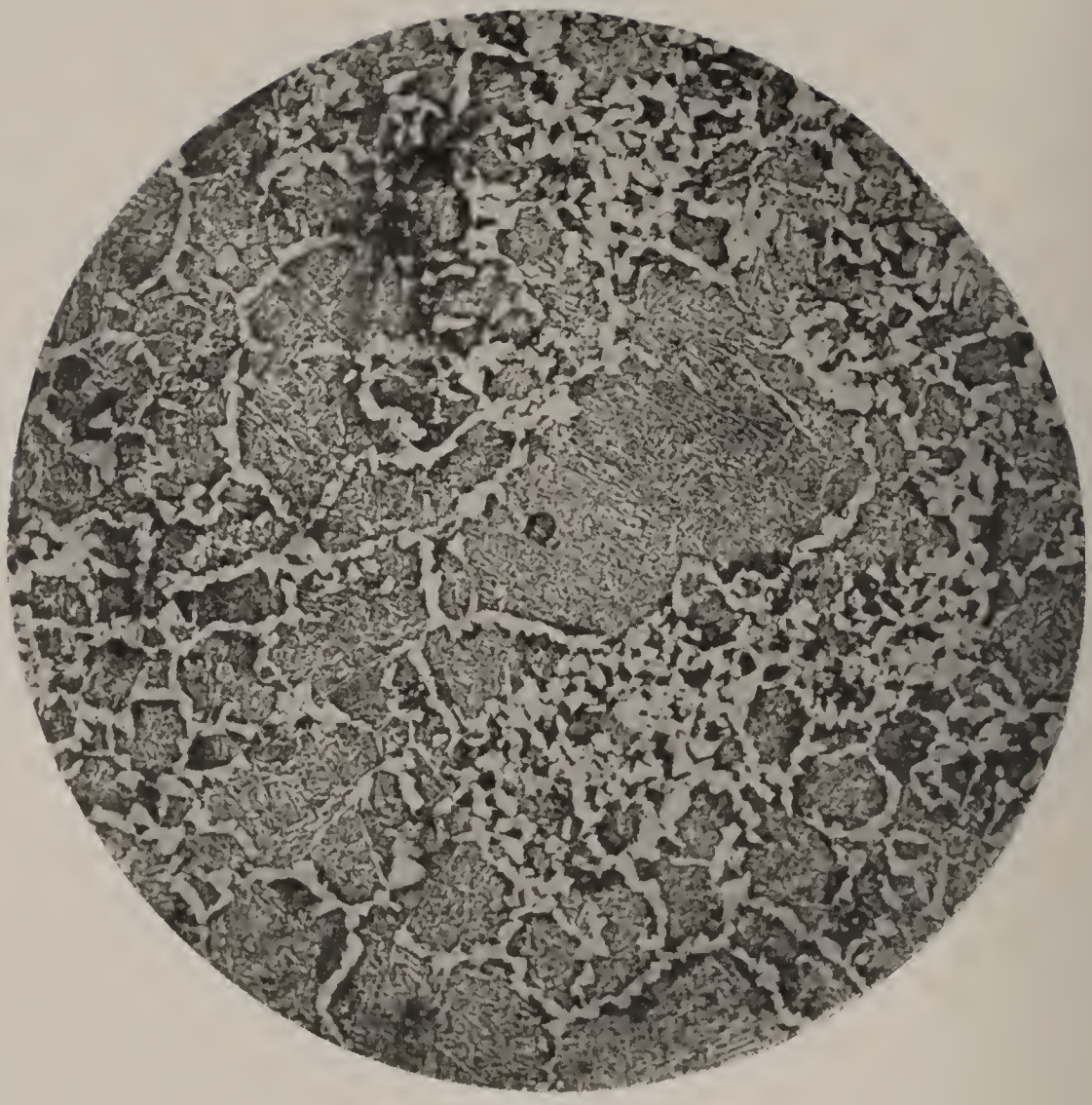
Tensile strength.	Yield point.	Elongation (per cent in 2 inches).	Per cent reduction.	Bend.
87500	54300	27.4	54.05	O. K.

The above illustration represents a structure which is **not acceptable** to the Bureau of Steam Engineering for Class An steel forgings.

Heat treatment.—The structure represented was obtained by annealing.

The white areas represent ferrite. The black areas represent pearlite.

This specimen was taken from a sleeve coupling for shafting for a battleship. The structure is not homogeneous. Broad ferrite streaks, such as the one here shown, render a forging unsuitable for use in shafting. The normal constituents are decidedly segregated.



Test No. 393C. Card No. 1. Inclosure (A).

CHEMICAL ANALYSIS.

C	S	Mn	Si	P	Cr	V
.28	.030	.49	.146	.007	.70	.14

PHYSICAL TESTS.

Tensile strength.	Yield point.	Elongation (per cent in 2 inches).	Per cent reduction.	Bend.
115620	100750	22.3	61.1	O. K.

The above illustration represents a structure which is **not acceptable** to the Bureau of Steam Engineering for class alloy steel forgings.

Heat treatment.—The structure represented was obtained by oil quenching followed by annealing.

The white areas represent ferrite. The black areas represent sorbitic pearlite.

This specimen was taken from a crank-shaft forging for a submarine. This structure is not uniform. A large grain size is found in some regions while in other regions the grain size is small.